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DISTRIBUTION AND SIZE OF BARNACLE *Chelonibia patula* FOULING BLUE CRAB *Callinectes amnicola* IN SOUTHEAST NIGERIA

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ABSTRACT

The distribution and occurrence of epibionts on the dorsal carapace, ventral carapace and chela of 325 specimens of *Callinectes amnicola* (De Rocheburne, 1883) (103.4 – 138.7 mm carapace width) from the Qua Iboe (QIRE) and Imo River (IRE) estuaries in southeast Nigeria was determined. The only ectosymbiont observed was cirriped barnacle, Chelonibia patula, mostly of smaller sizes (2.25 mm), infesting only 25-29% of intermoult crabs, more on females and in the Imo River estuary, with an average of four barnacles per crab, presupposing low level of epibiont-host interaction. There was no significant difference (P>0.05) in spatial distribution but epibionts were highest in the dry season in low salinity IRE (0.53‰) and in wet season in the medium-salinity QIRE (17.4‰). No public health risk has been reported among crab consumers in the study area. This study highlights epibiont-host interaction in the study area largely unknown for proper management of the fishery.

How to Cite

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INTRODUCTION

Epibionts are exclusively hardy, sessile marine invertebrates found in shallow and tidal brackish or saltwater living on or permanently attached on the exoskeleton of other organisms. Epibiosis is an association between two organisms, the epibiont (attaching organism) and a basibiont (substrate organism used for support of the epibiont) during the sessile phase of its life cycle without quantifying the degree of association, whether positive or negative (Wahl, 1989). Crustaceans such as cladocerans, copepods, cirripeds, isopods, amphipods and decapods serve as basibionts for protozoan and invertebrate epibionts (Ross, 1983). Epibionts are sessile suspension feeders with nektonic free-floating larval stages, but eventually attach themselves to almost any surface exposed to seawater (Wahl, 1989), therefore lack of available substrate is often the limiting factor for fouling organisms (Connel and Keough, 1985). Decapod crustaceans often populate soft sediment and their cuticle is an attraction substrate suitable for epibiont attachment (Abelló et al., 1990; Gili et al., 1993; Abelló and Corbera, 1996), before or after death. However, the timing of encrustations is important taphonomic paleo-ecologic information (Brandt, 1999). The epibionts may also be positioned to take advantage of currents generated by the animal or to seek protection (Crisp, 1983; Jeffrey and Overstreet, 2003).

This research investigated crustacean barnacle *Chelonibia patula* (Ranzani, 1820), a cirriped arthropod, closely associated with crabs and lobsters (Jeffries and Voris, 1983; Jeffries et al., 1992; Abelló and Corbera, 1996), as epibiont on the crustacean portunid crab, *C. amnicola*. Barnacle *C. patula*, bryozoan (*Alcyonidium polyoum* Hassall, 1841) and hydroid (*Hydractinia echinata*) just like blue crab require both inshore brackish waters and high salinity ocean waters to complete their life cycle and interact in symbiotic associations (Warner 1977). *C. patula* also occurs on a wide variety of substrates such as *Callinectes marginatus* (Edwards, 1801) (Stubbings, 1967) and *Portunus pelagicus* (Linneaus, 1758) (Shields 1992) and *Portunus validus* (Herklots, 1851) (Lawal-Are and Daramola, 2010).

The distribution, population dynamics, regulating factors, roles and interactions of epibionts with crustaceans are largely unknown. Their relationships range from predator-prey, parasitic (Abelló and Corbera, 1996; Mantelatto et al., 2003) or commensal (Zardus and Haedfield, 2004) to mutualistic and symbiotic interactions (Ross 1983; Mantelatto et al., 2003). The presence of epibionts is known to decrease host reproduction (Johansson, 2010) and increase their mortality, reduce the revenue from catch per unit of the fishers (Babu et al., 2012). Fishes consume infected zooplanktons more intensively than uninfected ones (Mantelatto et al., 2003). Thus epibionts can contribute to zooplankton decline by increasing host mortality both non-predatory and predatory, and inducing changes in zooplankton community.

In Nigeria, deep water crab *(Geryon maritae* Manning and Holthuis, 1981), ghost crab *(Ocypode african*), mangrove crab *(Goniopsis pelii* Herklots, 1851), fiddler crab (*Uca tangeri* Eydoux, 1835), *Callinectes amnicola, Callinectes pallidus* De Rocheburne, 1883, portunid or swimming crabs *(Callinectes marginatus*), *Cardisoma armatum* Herklots, 1851 and land crabs *(Gecarcinus weileri* Sendler, 1912) are common crab species found in brackish and marine environments (Amadi, 1990), and exploited mainly for commerce and food. Schneider (1990) notes that crab meat is rich in protein, vitamins and essential minerals like phosphorus, zinc, calcium, iron and little amount of (saturated) fat. It contains a high level of cholesterol and consumption should not exceed 300 mg per day.

Aspects of the biology of *C. amnicola* have been reported for the Imo River (Udoh et al., 2009), Cross River (Udoh et al., 2011) and Qua Iboe River estuaries, Nigeria (Udoh and Nlewadim, 2011). Udoh et al. (2009) estimated 92.7 mm CW and 116.11 mm CW as the average sizes at sexual maturity and first capture, L_c, respectively, for male *C. amnicola* in *IRE*. *C. amnicola* crabs in the study area exhibit brown, olive green, olive brown and orange green colour morphotypes and three moult stages. Generally the overall sex ratio of the crab populations in the *IRE* and *QIRE* slightly favoured males (1:0.89 and 1:1.94, respectively), comprising largely adult crabs (82 - 92%), in intermoult stage (86 - 87%), and with a tendency towards right-handedness (77 - 80%). The crabs were 109.85 ± 1.36 and 126.89 ± 49.45 g, 58.83 ± 2.78 and 62.48 ± 7.81 carapace length (mm), and 117.00 ± 5.65 and 124.50 ± 17.50 carapace width (mm), respectively, with the green morphotypes being larger in proportion and significantly longer and heavier than other crab morphotypes (Nlewadim et al., 2009; Udoh and Nlewadim, 2011). Male crabs were also observed to be heavier and longer than female crabs ($p < 0.05$). Ovigerous females with matured gonads (stages IV and V) constituted 10.95% of the crab population, while gonadosomatic index % were 2.72 ± 0.14 (0.00 − 49.55) and 6.25 ± 0.65 (0.00 − 79.54) and hepatosomatic index % - 4.61 ± 0.35 (0.00 − 156.27) and 4.91 ± 0.37 0.00 - 82.39) for adult males and females, respectively in the *IRE* (Nlewadim et al., 2009). However, Udoh et al. (2011) observed a preponderance of females over males (1:3.05), while females were significantly heavier but not significantly longer than males in the Cross River estuary.

Udoh and Jimmy (2015) described *C. amnicola* primarily as carnivores, with a tendency for carnivore-detritivore in *IRE* to omnivore-carnivore in *QIRE*, relative to abundance of food/prey items in its environment. Udoh and Nlewadim (2011) established that cheliped palm depth serves as a secondary sexual character being the character which affords high discriminatory values between crab sexes in *IRE* and *QIRE*. The above reports suggest that interpopulation variabilities of *C. amnicola* in these estuaries were phenotypic in nature and attributable to salinity differences; hence *C. amnicola* from the Qua Iboe and Imo River estuaries are of the same stock and could be subjected to similar management and conservation regulations. However large gaps exist in our knowledge of population biology of *C. amnicola* including the prevalence and effects of epibionts living on them. Thus, the aim of this research is to evaluate the seasonal pattern, distribution, composition and occurrence of epibionts on the chela, ventral and dorsal parts from the mesohaline Qua Iboe River estuary (17.4 ‰) and oligohaline Imo River estuary (0.53 ‰), and to compare them.

MATERIAL AND METHODS

A total of 147 and 178 specimens of portunid crab *C. amnicola* were randomly selected and sampled from the catches of artisanal fishers from Ukpenekang in Ibeno along the Qua Iboe River estuary and Uta Ewa along the Imo River estuary, respectively, from January to June 2009 (Fig. 1). All infested individuals were in intermoult. The collected samples were taken to the laboratory and stored in 10% formalin. Thereafter, they were identified using the scheme of Fischer et al. (1981) and measured. The carapace length of the crab was measured to the nearest centimeter from the edge of the frontal region to the tip of the carapace backwall using a vernier caliper. The carapace width was taken from the tip of the left dorsal spine to the tip of the right dorsal spine. The total weight of the crab was taken on a Sartorius top loading balance to the nearest 0.1 gram.

The attachment sites and abundance of individual barnacle on the (ventral and dorsal) body surface and the chela of each crab were observed, counted and recorded. The diameter of the barnacle shell was also measured using a vernier caliper and grouped into size-classes of 2, 4, 6, 8 and 10 mm.

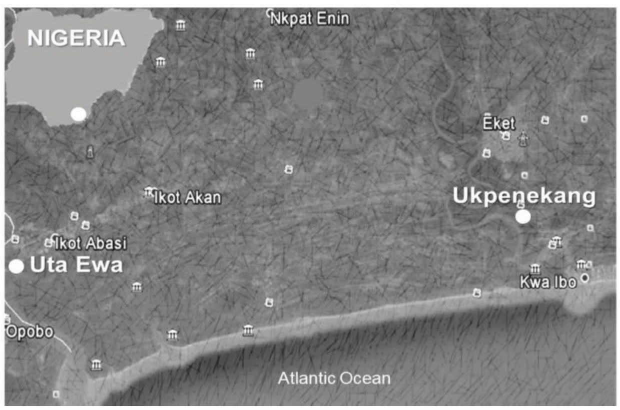

Fig 1. The coastal zone of Akwa Ibom State, southeastern Nigeria showing sampling points (●) along the Qua Iboe and Imo River estuaries (Inset: Map of Nigeria showing the study area)

The prevalence of infestation describes the proportion between infested hosts and the total number of crabs examined while intensity or incidence of infestation describes the number of epibionts present in each host (Ekanem et al., 2013). The relationship between prevalence (%) and intensity of the epibionts to the host size was evaluated using Spearman's rank correlation (r_s). Chi-square (χ^2) and *t*-Test were employed in evaluating intersexual variations, while *t*-Test was used in comparison of the two locations. The relationship between the number (*Y*) and size (*X*) of barnacles was established. All analyses were performed at 5% significance level (Zar, 1999).

RESULTS

Size composition

Carapace length of *C. amnicola* studied ranged between 56.9 – 69.8 mm and 51.4 – 66.7 mm, carapace width of 112.2 – 138.7 mm and 103.4 – 134.4 mm and total weight of 80.1 – 192.7 g and 73.6 – 173.5 g from the Qua Iboe and Imo River estuaries, respectively (Fig. 2).

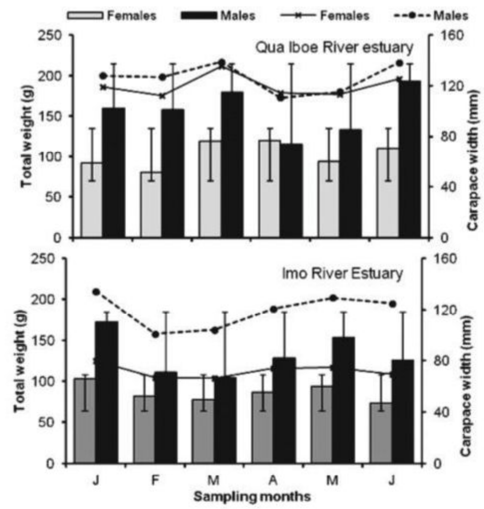

Fig 2. Size composition of male and female crabs sampled during the study (error bars indicate standard deviation of weight)

Distribution of barnacles

Barnacle *Chelonibia patula* was the only ectosymbiont attached to the crab species examined. Female crabs carried significantly ($P<0.05$) more epibionts than males in both estuaries: at least 11 - 48% and 12 - 68% of crabs sampled monthly and on overall basis (F:M %), 24:1 and 29:2 in the Imo River estuary (*IRE*) and Qua Iboe River estuary (*QIRE*), respectively. Females also constituted 82-100% of infected crabs encountered each month (Fig. 3). However, there was no significant difference ($P>0.05$) in the prevalence between male and female crabs (*QIRE*: $t = -4.10$, $P = 0.002$; $\chi^2 = 17.26$, $P = 0.004$, $df = 5$ and *IRE*: $t = -3.50$, $P = 0.006$; $\chi^2 = 16.995$, $P = 0.004$, $df = 5$) in both habitats.

Infestation of crabs by *C. patula* was observed in every month throughout the study period. The highest percentage of crabs infected with the epibiont was in June (63.4%) and February (47.1%) at the Imo and Qua Iboe River estuaries, respectively. The monthly occurrences of the barnacles in the study are shown in Figures 3, 4 and Table 1. There was no significant difference in the temporal ($P>0.05$, $t = 0.000041$) and seasonal occurrences ($t = 0.646263$, $P>0.05$) of barnacles on *C. amnicola*. The prevalence (%) of infestation at oligohaline-*IRE* and mesohaline-*QIRE* habitats did not vary significantly for *C. patula* ($t = -1.3438$, $P = 0.20872$ and Levenes's test of homogeneity of means, $P = 0.2562$); however, the oligohaline habitat showed a significantly higher mean prevalence of *C. patula* infestation (31.22%), when compared with the mesohaline habitat (18.87%). The intensity of infestation showed a similar trend with no significant variation between both habitats ($t = 0.098384$, $P = 0.92357$).

However, the trend showed an increase from three barnacles

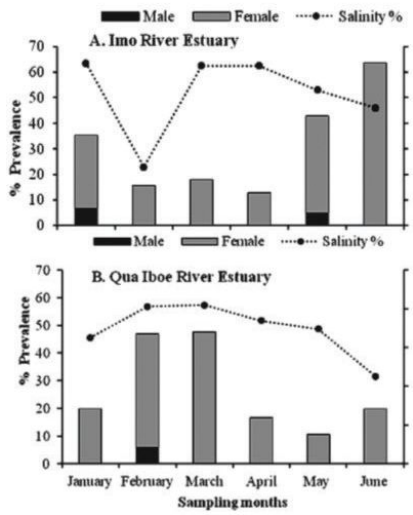

Fig 3. Monthly intersexual variation in prevalence of infected crabs in relation to salinity in the two habitats

on crab^{-1} in January to a peak of 10 barnacles crab^{-1} in March and dropping as the rains set in to six barnacles on crab^{-1} in June in the mesohaline Qua Iboe River estuary The monthly distribution in the oligohaline Imo River estuary showed a decrease from four barnacles on crab^{-1} in January to one barnacle on crab^{-1} in April and rising sharply to 10 barnacles on crab^{-1} in May and consequent drop in June (Table 1).

This indicates higher incidence rates in the dry season in the mesohaline habitat and in wet season in the oligohaline habitat, with increased numbers of epibiontic crab^{-1} infected. Seasonal occurrences indicate 23 out of 64 (35.9%) and 13 out of 84 (15.5%) were infected with epibionts in the Imo River Estuary (*IRE*), while the values were 20 out of 85 (23.5%) and 35 out of 93 (37.6%) in the Qua Iboe River Estuary (*QIRE*), in dry and wet seasons, respectively. This indicates higher prevalence rates in the dry season in the oligohaline habitat, while at the mesohaline habitat the wet season had more crabs infected with epibionts and these infestations appear to be related directly to salinity of the habitat (Fig. 4). The mean salinities were 0.53‰ for oligohaline habitat (*IRE*) and 17.4‰ for mesohaline habitat, *QIRE*.

Barnacles were also distributed and attached to different body parts of the crabs, particularly the carapace, abdomen and the chela at both habitats (Fig. 5). The epibionts were observed to be highly distributed on the dorsal carapace of the crab with an increase from about 40 barnacles in January to a peak of 127 barnacles both in May and March, in the oligohaline and mesohaline habitats, respectively. The ventral carapace and abdomen was fouled with 13-63 and 10-64 barnacles, in the respective habitats. The chela is the least preferred substrate for encrustation, being one to 13 and one to 16 barnacles in the oligohaline and mesohaline habitats, respectively. The ventral carapace

Table 1. Size distribution of epibionts on crabs in both estuarine locations

Months	No. of barnacles in each epibiont size class (mm)					No. of epibionts crab^{-1}	Mean size (mm) ± SD
	2	4	6	8	10		
Imo River Estuary							
January	104	9	6	2	6	4.03	2.80±2.00
February	10	11	8	6	12	4.6	3.26± 2.51
March	66	13	-	-	-	3.54	2.33± 0.75
April	19	6	4	-	3	0.82	3.63±2.54
May	158	39	2	3	2	9.67	2.58±1.32
June	74	24	4	5	-	3.18	2.87±1.56
Total	431	102	24	16	23	4.31	2.912±0.47
Qua Iboe River Estuary							
January	52	3	2	-	-	2.28	2.25 ± 0.85
February	30	21	17	1	3	3.82	3.94 ± 2.10
March	181	24	5	-	1	9.86	2.36 ±1.01
April	91	27	9	1	1	3.58	2.80 ±1.45
May	23	3	3	1	-	1.04	2.8 ±1.63
June	106	16	5	-	4	6.3	2.64 ±1.63
Total	**483**	**94**	**41**	**3**	**9**	**4.48**	**2.798 ± 0.60**

and abdomen was clean and without biofouling in April in the oligohaline Imo River estuary (Fig. 5).

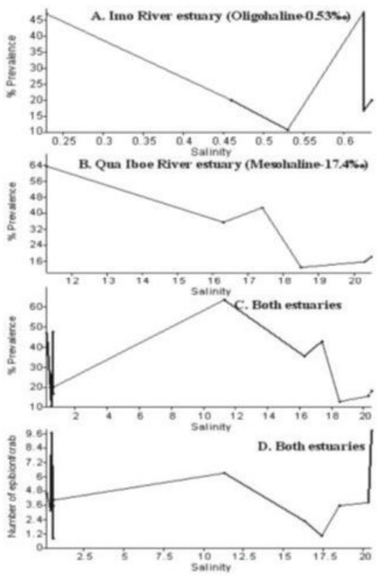

Fig 4. Prevalence and incidence of epibionts on crabs in relation to salinity in the two habitats

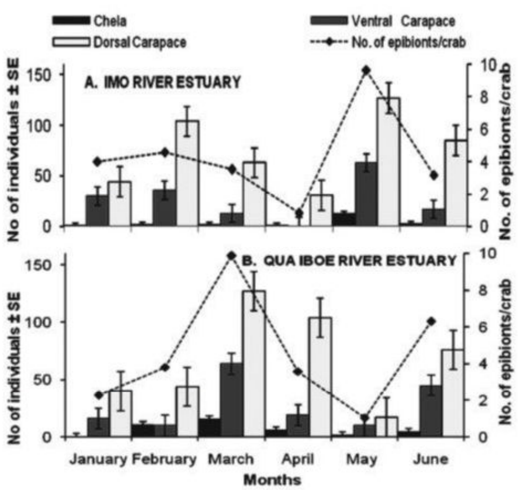

Fig 5. Distribution and number of barnacles on body parts of *C. amnicola*

Epibiont sizes

The epibionts encountered ranged from 2.0 mm to 10.0 mm with average diameter or mean sizes (± *SD*) of 2.912 ± 0.47 (2.33 - 3.63) and 2.798±0.60 (2.25 - 3.94) in the oligohaline and mesohaline habitats, respectively (Table 1). The least average diameters were encountered in the oligohaline and mesohaline habitats in March and January, respectively, and the highest in February, in both estuaries (Table 1). The monthly and overall mean sizes of epibionts on crabs between both rivers showed no significant difference (*t*-Test, $P>0.05$), though the Imo River estuary haboured epibionts of larger sizes. The number of barnacles in each epibiont size-class varied significantly ($P < 0.05$), with the smaller-sized (2 mm) epibiont dominating the population (431 - 481 in number), i.e. 72-77%. A significant exponential relationship was established between the number (Y) and size (X) of barnacles as: $Y = 702.e^{-0.9X}$, $r^2 = 0.853$ (Fig. 6). Average diameter of the barnacle *C. patula* attached to *C. amnicola* ranged from 2 mm to 10 mm with monthly average of 2.25 mm to 3.94 mm, while overall mean size of barnacle in both estuaries was 2.91 mm, with the smaller-sized epibiont dominating the population.

$Y = 528.2e^{-0.77X}$, $r^2 = 0.785$ (Imo River)

$Y = 1063.e^{-1.14X}$, $r^2 = 0.825$ (Qua Iboe River)

$Y = 702.e^{-0.9X}$, $r^2 = 0.853$ (mean number)

However, the mean number offers the best estimate ($Y = 702.e^{-0.9X}$), having the highest coefficient of determination ($r^2 = 0.853$).

Spearman correlation analysis of prevalence (%) and intensity of infestation by the epibionts in relation to the host size indicate no significant relationship, $P>0.05$ ($r_s = -0.43$, $P = 0.35$ and $r_s = -0.46$, $P = 0.37$; $r_s = 0.54$, $P = 0.24$ and $r_s = 0.46$, $P = 0.37$ for prevalence (%) and intensity in *QIRE* and *IRE*, respectively)

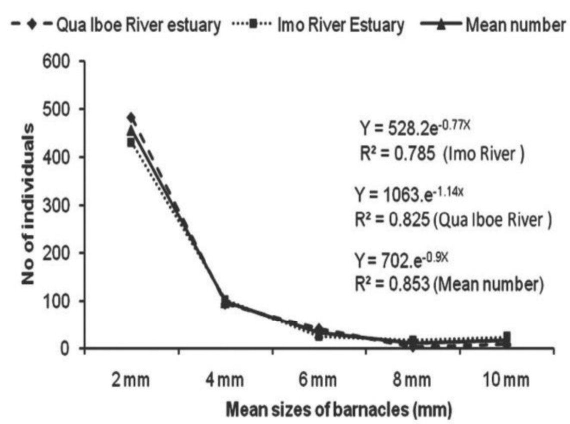

Fig 6. Relationship between number and size of barnacles on crab surfaces

DISCUSSION

Results from the present study reveal barnacle *Chelonibia patula* of the subclass Cirripedia was the only ectosymbiont observed on blue crabs *Callinectes amnicola* in the study area within the period. This is in agreement with the observation of Lawal-Are and Daramola (2010) on the same species off the Lagos coast, western Nigeria, while Ekanem et al. (2013) reportedly isolated the protozoan *Trichodina sp.*

from the skin of the same species in the Cross River estuary, Nigeria. The overall prevalence of *C. patula* was 25-29%, with blue crabs in the oligohaline Imo River estuary being more susceptible to infestation, particularly in the month of June.

Johansson (2010) noted that many of the comparisons involving epibiont-host relationships were not statistically significant and hence should be discussed regardless of statistical significance for the purposes of scientific discourse. Similarly, in this study, no significant differences (P>0.05) were observed with respect to the prevalence of *C. patula* on *C. amnicola* in spatial distribution, mean sizes of epibionts on crabs between both habitats and in host-size relationship; although possible explanations are formally presented vis-a-viz preliminary theories suggested in literature. The study also reveals female crabs were more susceptible to infestation than males in both estuaries. Elevated epibiont burden in female crabs was also observed by Overstreet (1983) and Mantelatto et al. (2003), while Childers et al. (1996) reported higher prevalence by *C. patula* on male crabs than the females, and compared to non-ovigerous females (Costa et al., 2010). This difference is related more to the functional biology of the epibiont as parasite. Johansson (2010) suggested that, in a laboratory study, the presence of barnacle epibionts like *C. patula* in large numbers on the shell surface of *Callinectes amnicola* modifies the host's morphology decreasing its fitness and defensive behaviors by increasing its surface area, which in turn increases drag on the organism and subsequently makes it more vulnerable to predation in its ambient environment. At such times, the epibiotic relationship is parasitic. This study observed the highest occurrence of epibionts (predisposing such parasitic relationships) at low salinities such as in the dry season at low salinity IRE (0.53 ‰) and in wet season in the medium-salinity QIRE (17.4 ‰), along with increased numbers of epibiont crab^{-1} infected. Moreover, barnacles tend to feed on host eggs. Females are preferred for the eggs they carry, serving as food sources for *C. patula* (Overstreet 1983; Costa et al., 2010). Female crabs are also preferred due to their life history. Female crabs tend to move with their egg mass after mating to the outer estuary and waters of higher salinity (> 25‰). Such high saline conditions are suitable for breeding and hatching of *C. patula* eggs (Lang, 1976). Epibionts infest only a portion of the host population depending on the specific age, sex and environment (Voris et al., 1994), and chemical cues (Molenock and Gomez, 1972).

Wahl (1989) notes that any exposed surface in seawater will become fouled. In this study, biofouling by barnacles was more prominent on the dorsal surface of the crabs than on the ventral surface or chela, probably because it was more exposed and better available to the settling barnacle larvae. This is in conformity with the observations of Babu et al. (2012). Mendez et al. (2014) observed the occurrence of barnacles on the dorso-lateral surface of crabs, particularly in areas such as the basal insertion of the chelipeds, walking appendages, ocular peduncles, jaws, mouth and the carapace. Mantelatto et al. (2003) report that *Chelonibia patula* is the typical barnacle found mostly on the dorsal carapaces of *Callinectes* and *Portunus* species. The dorsal surface is a biologically active surface made of chitin, calcium and microbial films (Babu et al., 2012) and hence presents a more attractive biofilm and ideal habitat for fouling or attachment by several sessile organisms. Pasternak et al. (2002) relate barnacle settlement and distribution more to larval settlement on the dorsal surface of host carapace, where light and water flow are more intense, than to abrasion and siltation processes of the (ventral surface of) exoskeleton when crab walks along the substrate (Key et al., 1997). The choice of the dorsal carapace may also be linked to the availability and health condition of the host in a suitable environment, absence of pollution of the particular area or it may indicate the host migration (Babu et al., 2012). Babu et al. (2012) documented more than 67 barnacles attached on the carapace and merus of a single crab *Charybdis natator* (Herbst, 1789), one to 54 on the dorsal side of *Portunus pelagicus*, one to 55 on carapace of *Charybdis cruciata* (Herbst, 1794), while on the ventral side of the crab the maximum observed was four tiny barnacles *C. patula* from the Gulf of Mannar and Palkbay coastal waters in India. Similar distribution of epibionts was recorded in this study (Table 1). This presupposes a low level of interaction with potential benefit for the host crabs, i.e. the abundance of *C. patula* provides protective role via camouflage (Wahl, 1989). Lawal-Are and Daramola (2010) observed only one crab had 31 barnacles attached to its carapace, with an average of three barnacles crab^{-1} on the same species off the Lagos coast. An average of four barnacles crab^{-1} were recorded in both habitats in this study. Both Lawal-Are and Daramola (2010) and Babu et al. (2012) could not establish any potential benefit to the host crabs, similar to this study. On the other hand, the potential benefits for *C. patula* living on motile benthic host substrates include gene flow, increasing the range of larval dispersal and expansion of the biogeographic distribution of the epizoans. Mendez et al. (2014) established that the barnacles utilize mobile basibionts as vectors to invade suboptimal habitats. The currents generated by the movement, breathing and/or feeding of the host may also improve the food supply to suspension feeding epizoans, as well as improve the removal of wastes produced by the epizoans (Crisp, 1983; Paperna, 1996).

Shields (1992) and Lawal-Are and Daramola (2010) observed an even distribution of *C. patula* on all sizes of *Callinectes sapidus* (Rathbun, 1896) and *Portunus validus* studied, such that on the average small sized crabs had as many barnacles attached to them as large crabs. However, Ekanem et al. (2011, 2013) reported higher prevalence of ecto- and endoparasites in fishes and crabs of lower size classes in the Great Kwa River and Cross River Estuary in southeast Nigeria, while Mantelatto et al. (2003) found a positive correlation between crab size and prevalence in *Callinectes danae* (Smith, 1869) and *Callinectes ornatus* (Ordway, 1863) hosting the barnacles in Ubatuba Bay, Saõ Paulo of Brazil. Abelló and Corbera (1996) also observed significant increase in epibiosis prevalence in relation to size in males and to moulting patterns in crustacean species (Abelló et al., 1990). The distribution of *C. patula* in this study was however independent of crab sizes similar to the report of Babu et al. (2012). Dependence of prevalence on crab sizes may be attributed to population structure and ecological integrity of the habitat. Mantelatto et al. (2003) suggests that variation in the distribution of parasites from one habitat to the other could be due to host-parasite relationship and abiotic factors like dissolved oxygen, temperature and pH, and the presence of such parasite in the immediate environment of the crab. Crab distribution in this study was apparently influenced by ambient salinity (Fig. 4) and exposed surface area (Fig. 5).

Epibiont sizes obtained in this study compare with 1.2 cm (average = 0.3 cm) for *C. patula* in the Lagos Lagoon, Nigeria (Lawal-Are and Daramola 2010) and 1-17 mm for *C. patula* on crabs from coastal waters in India (Babu et al., 2012). Abelló and Corbera (1996) also noted that individual epibionts settled on more protected areas of the carapace, like the coxae, had longer lengths than those settled on more exposed areas like the elevated/frontal areas of the dorsal carapace.

The epibiont preferentially infested individuals in intermoult, as similarly reported by Santos (2002). This indicates that initial colonization may more commonly occur after hardening of the exoskeleton (Jeffries et al., 1992; Santos and Bueno, 2002; Mantelatto et al., 2003). Moreover, immature crabs were unsuitable hosts because the short intermoult period does not allow for barnacle reproduction. In addition, Abelló et al. (1990) postulated that the size at which epibiosis becomes important may be related to host size at sexual maturity because epibionts are not able to settle and develop quickly enough to complete their life cycle on juvenile crabs. In this study epibionts were observed to settle on adult crabs (> 100 mm CW).

Johansson (2010) noted that many of the comparisons involving epibiont-host relationships were not statistically significant and hence should be discussed regardless of statistical significance for the purposes of scientific discourse. Similarly, in this study, no significant differences (P>0.05) were observed with respect to the prevalence of *C. patula* on *C. amnicola* in spatial distribution, mean sizes of epibionts on crabs between both habitats and in host-size relationship; possible explanations are formally presented vis-a-viz preliminary theories suggested in the literature.

The roles and interactions of epibionts with crustaceans largely vary and have been a source of public health concern, since they are highly cherished food items by coastal communities. They often reduce the condition of the crabs and create aesthetic problems reducing the market values and consumer acceptability of the infected crabs (Kuris and Lafferty, 1992). The competition for food between the crab and *C. patula* are unlikely since the former is a generalist-detritivore while the latter is a planktivorous filter-feeder (Marchinko, 2007). Mendez et al. (2014) obtained maximum size of sexually mature barnacles which could reproduce while fouling the crabs, making the crab an active dispersal agent of the barnacle exploring new areas. Babu et al. (2012) observed non-infested crabs were significantly heavier than infested crabs. Epibionts also have negative influence on the longevity/mortality, reproduction, egg survival and nutritive value of crabs. *Rhizocephalan barnacles* of the family Sacculinidae induce parasitic castration (Abelló and Corbera, 1996; O'Brien, 1999); their adult hosts are usually smaller than unparasitized crabs (O'Brien and Van Wyk, 1985), while parasitized male crabs acquire the wide abdomen characteristic of adult females (Hartnoll, 1967) and crabs bearing the external stage of the sacculinid do not moult (O'Brien and Skinner, 1990); when lodged in the gill chambers they can severely impair host respiration (Jeffries and Voris, 1983). Generally, most of these agents caused little or no pathological alteration in the crab host. More so, the abundance of epibionts in this study contribute very minimally or negligibly to crab weight.

Field observations by Mendez et al. (2014), however, indicate that crabs deposit-feed with great difficulties when barnacles growing at the base of the chelipeds prevent them from accessing their own mouth. Santos et al. (1987) further postulate that settlement and growth of barnacles in areas where the appendages articulate with the main carapace (a) may cause chelipeds and legs not to perform adequately during activities (like walking, swimming, feeding, mating, antipredatory escape or defence); (b) pedunculate eyes may be unable to close enough to stay wet and clean; (c) mouth pieces cemented together by barnacles decrease feeding performance; (d) ecosystem engineering and digging behavior of this crab species is likely to fail when chelipeds and legs are not functioning properly, and (e) survival under semiterrestrial conditions during low tides will be reduced when barnacles modify the shape of the web of channels distributed along and across the carapace and used to oxygenate the respiratory water circulating from and to the branchial chamber (Santos et al., 1987). Hartl et al. (2006) observed that biofouling has become a major problem in marine aquaculture and its removal from aquaculture installations and produce is expensive and labour-intensive. Fouling by tubeworms or barnacles could reduce their market value by up to 20% and fish may also be injured by brushing against encrusting species, opening up potential routes of infection.

However, unlike dead fish that float, dead crabs generally sink; hence, large mortalities often go unnoticed or under-reported (Ekanem et al., 2013). The true influence of several diseases, therefore, may be difficult to assess without intensive sampling. Although the present study focused strictly on ectosymbionts of *C. aminicola,* only *C. patula* was observed which poses no disease or pathological implications on its host and no health risk to crab consumers. Tan et al. (2002), however, noted that fouled aquaculture nets or cages harbor increased amount of *Neoparamoeba pemaquidensis* (Page, 1970) that causes amoebic gill disease in salmon. Such was not observed in this study.

The contribution of *C. amnicola* to the biodiversity of the study area is significant, particularly as an ecosystem engineer. Hence, extinction, reduction or extermination of portunid crabs could result in a large reduction in wetland habitats. Barnacle infestation also threatens conservation and dynamics of crab populations in the study area. David et al. (2002) report crab populations vary from year to year vis-a-viz abundance and predation rate of co-occurring predators (like other blue crabs, estuarine catfish *Chrysichthys nigrodigitatus* and croaker *Pseudotholithus elongatus*; Ekpo et al., 2014). Large numbers of young crabs fall prey to a number of predators. Blue crabs are subject to predation throughout their life cycle, particularly when they are soft during the moulting process. Environmental stress and the physical stress imposed by epibionts weaken crabs, predisposing them to infection, predation or disease. Low bottom vegetation also exposes crabs to predation during the juvenile stages and when adults are moulting (Mantelatto et al., 2003). Diseased animals become prey for other crabs or predators. Heavy predation of blue crabs might reduce the adult population.

Mantelatto and Fransozo (1999) documented an evidence of decreasing portunid populations revealing need for pro-active monitoring of natural stocks. The impact of epibiosis is often neglected in population dynamics and natural history of ecosystems. A brief remark on the impact of parasites earlier mentioned in this paper include influencing the growth, reproduction, egg survival, longevity and marketability of crabs. Parasites in crabs have also been a source of public health concern since they often cause disease which often increase the susceptibility to other diseases and reduce the nutritive value of host crabs and revenue derived from crab per unit effort.

CONCLUSION

This study reports a scanty infestation or fouling of *Chelonibia patula* on the highly cherished coastal delicacy *C. amnicola* in the study area. A few incidences of parasitism with high barnacle density of 10 per crab were also observed. Presently, there is no public record indicating disease or pathological implications or health risk to crab consumers. However, it is advisable to collect or market crabs for food consumption between January and April from oligohaline estuaries and in January and May from mesohaline estuaries, when the incidence/intensity rates and aesthetic problems are minimized. It is generally accepted that the cooking process kills the parasites and renders the crab meat completely safe to eat. Little or nothing has been reported about the biological relationships of crabs in the study area, including identification of parasites on crab populations. This study has contributed to the baseline data set that can be compared with future faunal studies of the area to increase awareness on epibiosis in crabs and to stimulate further investigations on these relationships with the goal of conserving crab wild populations.

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Sažetak

DISTRIBUCIJA I VELIČINA RAKOVA VITIČARA, *Chelonibia patula,* NA OBRAŠTAJU PLAVOG RAKA, *Callinectes amnicola,* U JUGOISTOČNOJ NIGERIJI

Određena je distribucija i pojava epibionta na leđnoj i trbušnoj strani oklopa i kliještima kod 325 uzoraka *Callinectes amnicola* (De Rocheburne, 1883) (103,4 - 138,7 mm širine oklopa) s ušća rijeka Qua Iboe (QIRE) i Imo (IRE) u jugoistočnoj Nigeriji. Jedini uočeni ekosimbiont je rak vitičar, *Chelonibia patula*, uglavnom manjih dimenzija (2,25 mm) na samo 25-29% rakova, više kod ženki na ušću rijeke Imo, s prosjekom od četiri vitičara po raku, što ukazuje na nisku interakciju epibionta-domaćina. Nije bilo statistički značajne razlike ($P > 0,05$) u odnosu na prostornu rasprostranjenost, ali epibionti su bili najviši u sušnom razdoblju u IRE niske slanosti (0,53 ‰), te u vlažnoj sezoni u QIRE srednje slanosti (17,4 ‰). Nije bilo utvrđenih rizika za zdravlje među konzumentima rakova u području istraživanja. Ovo istraživanje naglašava interakciju epibionta-domaćina u području istraživanja koje je u velikoj mjeri nepoznato po pravilnom upravljanju ribarstvom.

Ključne riječi: rakovi Encrusters, epibioza, zaraza, prevalencija

REFERENCES

Abelló, P., Corbera, J. (1996): Epibiont bryozoans (Bryozoa, Ctenostomatida) of the crab *Goneplax rhomboides* (Brachyura, Goneplacidae) off the Ebro delta (western Mediterranean). Miscellania Zoologica, 19, 2, 43-52.

Abelló, P., Villanueva, R., Gili, J. M. (1990): Epibiosis in deep sea crab populations as indicator of biological and behavioral characteristics of the host. Journal of the Marine Biological Association of the United Kingdom, 70, 687–695.

Amadi, A. A. (1990): A comparative ecology of estuaries in Nigeria. Hydrobiology, 208, 27-28.

Babu, M. Y., Durgekar, R., Devi, V. J., Ramakritinan, C. M., Kumaraguru, A. K. (2012): Influence of ciriped barnacles *Chelonibia patula* (Ranzani) on commercial crabs from Gulf of Mannar and Palk bay coastal waters. Research in Environment and Life Sciences, 5, 3, 109-116.

Brandt, D. S. (1999): Epizoans on Flexicaymene [Trilobita] and implications for trilobite paleoecology. Journal of Paleontology, 70, 442-449.

Childers, R. K., Reno, P. W., Olson, R. E. (1996): Prevalence and geographic range of *Nadelspora cancei* (microspora) in Dungeness crab *Cancer magister*. Web of Science, 24, 135–142.

Connel, J. H., Keough, M. J. (1985): Disturbance and patch dynamic of subtidal marine animals on hard substrata. In: Pickett STA, White PS, editors. The Ecology of Natural Disturbance and Patch Dynamic. New York: Academic Press; p. 125 – 151.

Costa, T. M., Christofoletti, R. A., Pinheiro, M. A. A. (2010): Epibionts on *Arenaeus cribrarius* (Brachyura: Portunidae) from Brazil. Zoologia, 27, 3, 387–394.

Crisp, D. J. (1983): *Chelonibia patula* (Ranzani), a pointer to the evolution of the complemental male. Marine Biology Letters, 4, 5, 281-294.

Ekanem, A. P., Eyo, V. O., Ekpo, I. E., Bassey, B. O. (2013): Parasites of Blue Crab (*Callinectes amnicola*) in the Cross River Estuary, Nigeria. International Journal of Fisheries and Aquatic Studies, 1, 1, 18-21.

Ekanem, A. P., Eyo, V. O., Sampson, A. F. (2011): Parasites of landed fish from Great Kwa River, Calabar, Cross River State, Nigeria. International Journal of Fisheries and Aquaculture, 3, 12, 225-230.

Ekpo, I. E., Essien-Ibok, M. A., Nkwoji, J. N. (2014): Food and feeding habits and condition factor of fish species in Qua Iboe River estuary, Akwa Ibom State, southeastern Nigeria. International Journal of Fisheries and Aquatic Studies, 2, 2, 38-46.

Fischer, W., Bianchi, G., Scott, W. B. (1981): FAO Species Identification Sheets for Fishery purposes. Vol. VI. Eastern Central Atlantic Fishing Area 34 and Part of 47. Rome, FAO.

Gili, J. M., Abello, P., Villanueva, R. (1993): Epibionts and intermoult duration in the crab *Bathynectes piperitus*. Marine Ecology Progress Series, 98, 107-113.

Hartl, M. G. J., Watson, D., Davenport, J. D. (2006): Biofouling in the Marine Aquaculture Industry, with particular reference to Finfish – current status and future challenges. London: The Crown Estate; 56p.

Hartnoll, R. G. (1967): The effects of sacculinid parasites on two Jamaican crabs. Journal of Linnean Society (Zoology), 46, 275–295.

Jeffrey, S. D., Overstreet, R. M. (2003): The Blue Crab: Diseases, Parasites and Other Symbionts. Harold W. Manter Laboratory of Parasitology; 426p.

Jeffries, W. B., Voris, H. K. (1983): The distribution, size, and reproduction of the penunculate barnacle, *Octolasmis mulleri* (Coker, 1902), on the blue crab, *Callinectes sapidus* (Rathbun, 1896). Fieldiana Zoology New Series, 16, 1–10.

Jeffries, W. B., Voris, H. K., Poovachiranon, S. (1992): Age of the mangrove crab *Scylla serrata* at colonization by stalked barnacles of the genus *Octolasmis*. Biological Bulletin, 182, 188–194.

Johansson, J. (2010): An epibiont mediated increase in the susceptibility of *Mytilus edulis* to predation by *Nucella lapillus*. Studies by Undergraduate Researchers at Guelph, 4, 1, 65-71. Available at: <https://journal.lib.uoguelph.ca/index. php/surg/article/view/1114/1800>. Date accessed: 16 Aug. 2014.

Key, Jr, M. M., Volpe, J. W., Jeffries, W. B., Voris, H. K. (1997): Barnacles fouling of the blue crab *Callinectes sapidus* at Beaufort, North Carolina. Journal of Crustacean Biology, 17, 3, 424-439.

Kuris, A. M., Lafferty, K. D. (1992): Modeling crustacean fisheries: effects of parasites on management strategies. Canadian Journal of Fishery and Aquatic Science, 49, 327– 336.

Lang, W. H. (1976): The larval development of the barnacles *Octolasmis miilleri* and *Chelonibia patula*. American Zoology, 16, 219.

Lawal-Are, A. O., Daramola, T. O. (2010): Biofouling of the barnacle, *Chelonibia patula* (Ranzani) on two portunid crabs, *Callinectes amnicola* (De Rocheburne) and *Portunus validus* (Herklots) off Lagos Coast, Nigeria. European Journal of Scientific Research, 44, 3, 520-526.

Mantelatto, F. L., Fransozo, A. (1999): Reproductive biology and moulting cycle of the crab *Callinectes ornatus* (Decapoda, Portunidae) from the Ubatuba region, Sao Paulo, Brazil. Crustaceana, 72, 63–76.

Mantelatto, F. L., O'brien, J. J., Biagi, R. (2003): Parasites and symbionts of crabs from Ubatuba Bay, Sao Paulo State, Brazil. Comparative Parasitology, 70, 2, 211–214.

Marchinko, K. B. (2007): Feeding behavior reveals the adaptive nature of plasticity in barnacle feeding limbs. Biological Bulletin, 213, 12-15.

Mendez, M. M., Sueiro, M. C., Schwindt, E., Bortolus, A. (2014): Invasive barnacle fouling on an endemic burrowing crab: mobile basibionts as vectors to invade a suboptimal habitat. Thalassas, International Journal of Marine Sciences, 30, 1, 39-46.

Molenock, J., Gomez, E. D. (1972): Larval stages and settlement of the barnacle *Balanus* (*Conopea*) *galeatus* (L.) (Cirripedia Thoracica). Crustaceana, 23, 100-108.

Nlewadim, A. A., Ofor, C., Udoh, J. P. (2009): Size composition and population characteristics of the swimming crab *Callinectes amnicola* (De Rocheburne, 1883) (Crustacea, Brachyura, Portunidae) in the Imo River estuary, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 5, 2-4, 47-60.

O'Brien, J. J. (1999): Parasites and reproduction. In. Pearse, J, editor. Encyclopedia of Reproduction. Vol. 3. San Diego, California: Academic Press; p. 638 – 646.

O'Brien, J. J., Skinner, D. M. (1990): Overriding of the moult-inducing stimulus of multiple limb autotomy in the mud crab *Rhithropanopeus harrisii* by parasitization with a rhizocephalan. Journal of Crustacean Biology, 10, 440 – 445.

O'Brien, J. J., Van Wyk, P. (1985): Effects of crustacean parasitic castrators (epicaridean isopods and rhizocephalan barnacles) on growth of their crustacean hosts. In. Wenner, A. M., editor. Crustacean Issues, Factors in Adult Growth. Vol. 3. Rotterdam, The Netherlands: A. A. Balkema Press; p. 191–218.

Overstreet, R. M. (1983): Metazoan symbionts of crustaceans. In. Provenzano, A. J., editor. The Biology of Crustacea: Pathobiolgy. Vol. 6. New York: Academic Press; p. 156–210.

Paperna, I. (1996): Parasites, infections and diseases of fishes in Africa. An update. CIFA Technical Paper, 31, 157-170.

Pasternak, Z., Abelson, A., Achituv, Y. (2002): Orientation of *Chelonibia patula* (Crustacea: Cirripedia) on the carapace of its crab host is determined by the feeding mechanism of the adult barnacles. Journal of the Marine Biological Association of the United Kingdom, 82, 583-588.

Ross, D. M. (1983): Symbiotic relations. In. Vernberg, F. J., Vernberg, W. B., editors. The biology of Crustacea: behavior and ecology, vol. 7, 383p. New York: Academic Press; p. 163-212.

Santos, C., Bueno, S. L. S. (2002): Infestation by *Octolasmis lowei* (Cirripedia: Poecilasmatidae) in *Callinectes danae* and *Callinectes ornatus* (Decapoda: Portunidae) from Sao Sebastiao. Journal of Crustacean Biology, 22, 241–248.

Santos, E. A., Baldisseroto, B., Blanchini, A., Colares, E. P., Nery, L. E. M., Manzoni, G. C. (1987): Respiratory mechanisms and metabolic adaptations of an intertidal crab, *Chasmagnathus granulate* (Dana, 1851). Comparative Biochemistry and Physiology Part A: Physiology, 88, 21-25.

Santos, S. (2002): Symbiosis between *Portunus spinimanus* Latreille, 1819 (Decapoda, Portunidae) and *Octolasmis lowei* (Darwin, 1852) (Thoracica, Poecilasmatidae) from Ubatuba, São Paulo, Brazil. In: Scobar-Briones, E. E., Alvarez, F., editors. Modern Approaches to the study of Crustacea, 376p. New York: Kluwer Academic Publishers; p. 205-209.

Schneider, W. (1990): FAO Species identification sheet for fishery purpose. Field guide to the Commercial Marine resources of the Gulf of Guinea. Rome: FAO; 268.

Shields, J. D. (1992): Parasites and symbionts of the crab *Portunus pelagicus* from Moreton Bay, eastern Australia. Journal of Crustacean Biology, 12, 94–100.

Stubbings, H. G. (1967): Cirriped fauna of tropical West Africa. Bulletin of the British Museum Natural History. Zoology, 15, 1-39.

Tan, C. K. F., Nowak, B. F., Hodson, S. L. (2002): Biofouling as a reservoir of *Neoparamoeba pemaquidensis* (Page, 1970), the causative agent of amoebic gill disease in Atlantic salmon. Aquaculture, 210, 49-58.

Udoh J. P., Jimmy, U. U. (2015): Dietary spectrum, dispersity and overlaps of blue crab (*Callinectes amnicola*, De Rocheburne) from Southeast Nigeria. Croatian Journal of Fisheries, 73, 162-169.

Udoh, J. P., Holzlohner, S., Ekanem, S. B. (2011): Population Structure and Biometric Relationships of *Callinectes amnicola* De Rocheburne, 1883 (Crustacea, Brachyura, Portunidae) from the Cross River Estuary, Nigeria. Nigerian Journal of Fisheries, 8, 145 – 153.

Udoh, J. P., Nlewadim, A. A. (2011): Population characteristics of the swimming crab *Callinectes amnicola* De Rocheburne, 1883 (Crustacea, Brachyura, Portunidae) in the Qua Iboe River estuary, Nigeria. AACL Bioflux, 4, 3, 395-405.

Udoh, J. P., Nlewadim, A. A., Ofor, C. (2009): Maturity estimation in male swimming brachyuran crab, *Callinectes amnicola* (De Rocheburne, 1883) (Decapoda, Portunidae) in the Imo River estuary, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 5, (2-4), 61-71.

Voris, H. K., Jeffries, W. B., Poovachiranon, S. (1994): Patterns of distribution of two barnacle species on the mangrove crab, *Scylla serrata*. Biological Bulletin, 187, 346-354.

Wahl, M. (19899: Marine epibiosis I: fouling and antifouling: some basic aspects. Marine Ecology Progress Series, 58, 175-189.

Warner, G. F. (1977): The biology of crabs. London: Paul Elek Scientific Book Ltd., 202p.

Zar, J. H. (1999): Biostatistical analysis. New Jersey: Prentice-Hall Inc.; 662p.

Zardus, J. D., Haedfield, M. G. (2004): Larval development and complemental males in *Chelonibia testudinaria,* a barnacle commensal with sea turtles. Journal of Crustacean Biology, 24, 3, 409-421.

